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ARIZONA INTELLIGENT VEHICLE RESEARCH PROGRAM – PHASE THREE: 2002 – 2003

This Research Note summarizes Phase Three of a long-term Intelligent Transportation Systems (ITS) research program by the Arizona Department of Transportation (ADOT) to study cooperative vehicle and infrastructure-based guidance technologies. ADOT's Arizona Transportation Research Center (ATRC) in Phoenix has conducted this research project as an in-house effort.

Introduction

Phase Three of Arizona's advanced-vehicle research, the 2002-03 winter season, was Year Five of the program. In four previous years, the project efforts focused on advanced lane positioning and predictive guidance technologies that required a complex roadway infrastructure component. This concluding Phase Three of the project, in contrast, has evaluated two commercial on-board driver-warning systems on seven snowplow routes across northern Arizona.

BACKGROUND TO PHASE THREE

Phase One of the ADOT Intelligent Vehicle Research Program (1997-2000) involved Arizona demonstrations of Intelligent Vehicle (IV) and Automated Highway System (AHS) concepts. The program soon became focused specifically on snowplow research, as a promising near-term application to enhance the safety and efficiency of ADOT winter maintenance operations.

In Phase One, the ATRC partnered with the California Department of Transportation (Caltrans) to field-test their prototype Advanced Snowplow (ASP) in Arizona. The project developed a three-mile test lane on US 180 near Flagstaff in northern Arizona. This site allowed Caltrans to diversify their research experience in different weather and terrain conditions, with a unique pool of Arizona snowplow operators. For two winters in the Phase One program, ADOT maintenance crews trained on and evaluated the Caltrans lane-guidance system in four-week test cycles.

In Phase Two (2000-01), the project sought to equip an ADOT snowplow with a guidance system for long-term testing. Caltrans could only assign their newest RoadView™ ASP to Arizona for four weeks each winter, which did not allow for a thorough evaluation of the Caltrans system and its components. The project's Technical Advisory Committee (TAC) therefore made a decision to procure and commission similar snowplow vehicle guidance technology in Arizona.

At this time, the Caltrans program did not have staff resources to support a second ASP system outside of California. Also, the RoadView ASP was a developmental prototype. Many key components were not packaged systems, but were unique or even hand-built. Therefore, ADOT acquired a 3M Lane Awareness System (LAS) with five miles of 3M's magnetic striping tape. The tape was installed in the roadway at a site near Flagstaff, in a construction project on US 89.

ADOT continued its long-term program with Caltrans in Phase Two, with a new goal to compare both guidance systems operationally in similar weather and road conditions. Phase Two was not a complete success, for reasons that were mostly technical. Both test snowplows had various ASP system issues, and at the 3M site, temporary lane striping did not match the embedded tape.

These problems dictated a fourth testing winter, Phase Two(b) for ADOT, and in 2001-02 the project finally achieved a higher level of success. The Caltrans RoadView ASP and the ADOT-3M plow both were reliable and effective in their respective training, evaluation and operational phases, but the Phase Two(b) winter had less than half of the normal snowfall. Also at this point, ADOT recognized that the current costs of either roadway-infrastructure system would limit their application for Arizona, and the project was steered toward new on-board concepts.

PHASE THREE: NEW RESEARCH DIRECTIONS

This Phase Three research report, on the 2002-03 season, covers the fifth and final project year of the ADOT-ATRC evaluation program for advanced snowplow systems. The research efforts for Year Five were refocused to a thorough and complete evaluation of two promising on-board commercial warning systems. These two systems were the Bendix XVision passive-infrared (IR) night vision system, and the Eaton VORAD EVT-300 collision warning radar system (CWS).

The fundamental problem to be addressed by this research program is poor visibility for plow operators in severe winter storms. The new on-board warning systems do not provide the 3M or Caltrans predictive guidance abilities to keep snowplows moving in very poor visibility, but they do improve operator awareness of conditions, hazards, and potential obstacles in the road ahead.

The project goals were to determine the state of development, effectiveness, flexibility, and reliability of the two on-board driver-warning systems in winter storms, and, to identify the key factors for their successful implementation for snowplowing in rural states such as Arizona.

Winter 2002-03: Phase Three Research Plan

With the project newly focused on tests with off-the-shelf, self-contained, on-board systems, the ATRC's research plan was both simpler and more complex. The project's key mandates were to evaluate practical, affordable warning systems, and, to expand the playing field to involve more winter maintenance stakeholders and decision-makers. The research plan for 2002-03 would therefore expand the number of active project partners across three ADOT maintenance districts, and a total of seven test locations were identified.

The TAC's goal was to place at least one radar and one XVision system in each of ADOT's three northern districts across the Interstate 40 corridor. The project obtained four CWS radar systems and three IR night vision systems. The units were assigned to snowplows on both Interstate and state highway routes, and the plows had the flexibility to work on other routes as needed.

Arizona's evaluation program for Phase Three evolved from the partnership with the Caltrans test program. Over four winters, various report formats had been developed and standardized as much as possible for both ASP concepts. ATRC continued to employ the basic project reporting tools, including shift activity reports and surveys of driver perceptions and preferences.

The two new suppliers had to be considered in the research plan and evaluation approach. Both systems were commercial units designed as driver-support systems for long-haul transport fleets. The CWS radar system was widely marketed, and Eaton was not focused on niche markets such as snowplowing. The Bendix IR night vision was less widely distributed, and their program was still exploring the marketing potential for specialty vehicle applications.

As a result, the ADOT evaluation would seek driver feedback with a Bendix incident report to describe events when the system did or did not give a warning, or, impacted a driver's decisions. While not required by Eaton, the ATRC also used a similar event report for the CWS radar units, providing one more consistent evaluation tool for both on-board systems.

Winter 2002-03: Training & Evaluation

The Year Five evaluation of these two off-the-shelf commercial systems was focused only on the key drivers assigned to each of the project snowplows. The main emphasis was on their level of effectiveness for the ADOT snowplow operators in storms at the widely scattered test sites.

There was a learning curve for the commissioning of the two driver-warning systems. The Eaton VORAD system was fully developed, with extensive installation, training, and trouble-shooting manuals, and an introductory videotape. This level of training support was required for driver acceptance due to the sophistication of the radar concept and its array of warning signals.

Bendix, on the other hand, offered a night vision concept that was clear and intuitive, with only limited training material and operating guidelines. Still, these aids were needed to ensure that every driver understood the abilities and limitations of the thermal imaging equipment.

Overall, the evaluation was ongoing rather than episodic. The ATRC provided basic shift reports for storm events so that driver comments or system issues could be documented without adding too much more paperwork. These reports were augmented with frequent project meetings and by periodic driver surveys on both systems, including a final survey at the end of the season.

Winter 2002-03: Operational Activities

The project's Phase Three, Year Five winter was a meteorological disappointment, but the winter weather was adequate to give the two systems a fair evaluation across the seven test sites. There were 14 storms with an inch or more of snow, compared to only ten in 2001-02. The snowfall at Flagstaff for 2002-03 totaled 55 inches, compared to a 30-year historic average of 107 inches.

The last of the seven project snowplows was fully operational by early February 2003, and all were employed on storm watch, materials application, and plowing activities. Overall, the seven snowplows logged a total of 37,250 miles in these operations, with 140 use-days from October to April, despite having only about 50 percent of the normal regional snowfall.

WINTER 2002-03 PROJECT RESULTS: ON-BOARD SYSTEMS

The Phase Three winter was the first season of testing and storm operations for the six newly-equipped project snowplows, and the Phase Two ADOT-3M snowplow was the seventh.

This level of deployment definitely fulfilled the TAC's fundamental mandate for the research project. This relatively mild winter still validated the research plan, and it effectively demonstrated the long-term potential for the selected on-board commercial systems.

There are some issues, however, for wider distribution of units in the field. Driver acceptance is one concern, as the test plows were selected based on their operational route assignments. Some drivers were enthusiastic about the new systems and others were not. There is no clear pattern to the level of acceptance, but many factors may apply. With the wide dispersal of the units and the limited training program, drivers were really on their own. There were also problems with snow and ice buildup on the night vision camera lens that its heating element could not overcome.

Operational results were positive overall, despite the few major storms that occurred. The ADOT operators had no failures or reliability problems with the on-board systems through the winter, except as noted above. For the more committed drivers, their level of confidence was good with both the warning radar and the night vision system. The project concluded this fifth season with TAC recommendations to extend both field evaluations, to work to overcome the snow buildup issue for the XVision system, and to promote these two solutions within ADOT and regionally.

1997–2003 PROGRAM RESULTS: ADVANCED VEHICLE SYSTEMS

The key result of five winters of ADOT's snowplow research program is the confirmation that effective and reliable driver-assistance systems exist that, if deployed, can provide significant benefits to Arizona for winter maintenance operations in extreme storm conditions. The benefits include more efficient plowing operations, which will enhance the safety of ADOT snowplow operators and the traveling public.

This project has validated the potential of roadway-based vehicle guidance concepts developed by 3M and by the Caltrans program, but they are not the best solution for Arizona at their current cost levels. The project has also shown the potential in fleet operations for collision warning radar and night vision systems, although each has basic design limitations for snowplowing. Further field experience is needed to verify full winter storm functionality, but both on-board warning systems are operationally effective, robust and reliable.

The extra cost of equipping a snowplow with either on-board warning system would be minimal, and it is far less than the economic impact of even a single injury accident. The project recommends further operational use of both systems for a second winter, to confirm that wider implementation of these units in Arizona can meet the local districts' needs.

The full report: *Arizona Intelligent Vehicle Research Program – Phase Three: 2002 - 2003* by Stephen R. Owen P.E., of the Arizona Transportation Research Center (Arizona Department of Transportation, report number FHWA-AZ-03-473(4), published January 2004) is available on the Internet at http://www.dot.state.az.us/ABOUT/atrc/Index.htm. Educational or governmental agencies may order print copies from the Arizona Transportation Research Center, 206 S. 17th Avenue, MD 075R, Phoenix, AZ 85007; FAX 602-712-3400. Businesses may order copies through ADOT's Engineering Records Section, by calling 602-712-7498.